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TITANIUM ALLOY HAVING GOOD CREVICE CORROSION RESISTANCE

[Taisukima Fushokusei ni Sugureta Chitan Gōkin]

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Specification

1. Title

TITANIUM ALLOY HAVING GOOD CREVICE CORROSION RESISTANCE

2. Claims

(1) A titanium alloy having good crevice corrosion resistance, characterized by comprising, by weight,

one or more elements of the platinum group:

total 0.01 to 0.12 percent,

one or more from among Nb, Zr, Hf, Ta, and Bi:

total 0.05 to 2.00 percent,

with the remainder essentially being comprised of titanium.

(2) A titanium alloy having good crevice corrosion resistance, characterized by comprising, by weight,

one or more elements of the platinum group:

total 0.01 to 0.12 percent,

one or more from among Nb, Zr, Hf, Ta, and Bi:

total 0.05 to 2.00 percent,

one or more from among Ni and Co:

total 0.05 to 2.00 percent,

with the remainder essentially being comprised of titanium.

[1] Numbers in the margin indicate pagination in the foreign text.

(3) A titanium alloy having good crevice corrosion resistance, characterized by comprising, by weight,

one or more elements of the platinum group:

total 0.01 to 0.12 percent,

one or more from among Nb, Zr, Hf, Ta, and Bi:

total 0.05 to 2.00 percent,

one or more from among Mo and W:

total 0.05 to 2.00 percent,

with the remainder essentially being comprised of titanium.

(4) A titanium alloy having good crevice corrosion resistance, characterized by comprising, by weight,

one or more elements of the platinum group:

total 0.01 to 0.12 percent,

one or more from among Nb, Zr, Hf, Ta, and Bi:

total 0.05 to 2.00 percent,

one or more from among Ni and Co:

total 0.05 to 2.00 percent,

one or more from among Mo, W, and V,

with the remainder essentially being comprised of titanium./2

3. Detailed Description of the Invention

<Industrial Field of Application>

The present invention relates to titanium alloys that have good resistance to crevice corrosion and are relatively inexpensive.

<Prior Art>

At the outset of production on an industrial scale, titanium, with its characteristic light weight and strength, played a central role in the aviation industry and the like. Since it also has good corrosion resistance, titanium has also recently been widely employed as a material in chemical industry equipment, thermoelectric and atomic power generation equipment, seawater desalination equipment, and the like. However, although titanium generally has good corrosion resistance, the places where good resistance to corrosion is utilized are environments with oxidizing acids such as nitric acid and neutral chloride environments such as seawater. The resistance of titanium to corrosion in the nonoxidizing acid (hydrochloric acid, sulfuric acid, and the like) environments relatively frequently encountered in the chemical industry and its resistance to crevice corrosion in high-temperature chlorine environments have proven extremely unsatisfactory.

Accordingly, Ti-Pd alloys were developed for use in such nonoxidizing acid environments and environments where crevice corrosion is a concern. In particular, these alloys have been widely employed in environments containing hydrochloric acid. The addition of a small quantity (about 0.2 weight percent) of Pd to titanium greatly decreases the hydrogen overvoltage, utilizing the phenomenon of keeping the spontaneous potential within the passive state range.

However, the incorporation of a relatively large quantity of precious metal into the above Ti-Pd alloys evaluated as having corrosion resistance makes them expensive. Accordingly, there is a problem in that their use must be limited.

Additionally, a titanium alloy in which small quantities of Ni and Mo are added in combination with the main objective of enhancing resistance to crevice corrosion has been proposed (Japanese Patent Application Publication No. Sho 50-130614). Although this alloy achieves relatively good strength, it affords poor processability and has much poorer resistance to crevice corrosion than the above-described Ti-Pd alloys. Thus, it cannot be considered a satisfactory material. Further, its poor processability have hindered its wide application.

<Problems to Be solved by the Invention>

Due to the above-stated problems, the present inventors conducted extensive research into providing inexpensive titanium alloys that had good resistance to crevice corrosion rivaling that of Ti-Pd alloys, had good general resistance to corrosion, such as resistance to corrosion in nonoxidizing acid environments, and afforded good processability on a par with that of industrially employed pure titanium. This resulted in the following discoveries.

(a) Although the addition of trace quantities of elements of the platinum group (Ru, Rb, Pd, Os, Ir, and Pt) is essential to markedly improving the resistance to crevice corrosion of titanium without compromising processability, when a titanium alloy is configured by combining one or more from among Nb, Zr, Hf, Ta, and Bi in addition to these elements of the platinum group, the effect of reducing the hydrogen overvoltage of elements of the platinum group and the effects of stabilizing and strengthening passive-state films on titanium of Nb, Zr, Hf, Ta, and Bi combine, achieving markedly improved resistance to crevice corrosion that cannot be fully achieved by using elements of these groups separately.

(b) Accordingly, the combined addition of one or more from among Nb, Zr, Hf, Ta, and Bi makes it possible to reduce the

content of expensive elements of the platinum group while maintaining the extremely good resistance to corrosion of the titanium alloy.

(c) When one or more from among Mo, W, and V is further combined in the above-described alloy containing a trace amount of an element of the platinum group and Nb, Zr, Hf, Ta, and/or Bi, the effects of "stabilizing the passive-state film formed on the titanium surface and further enhancing the corrosion resistance, particularly the resistance to crevice corrosion" are achieved due to acidic molybdic acid ions, tungstic acid ions, or vanadic acid ions produced in crevices by the dissolution of the Mo, W, and/or V in the ambient liquid. These effects are achieved in combination with the effect of reducing the hydrogen overvoltage of elements of the platinum group and the effects of stabilizing and strengthening passive-state films of Nb, Zr, Hf, Ta, and Bi on titanium. Further, the corrosion resistance, primarily the crevice corrosion resistance, of the titanium alloy is greatly enhanced without a deterioration in processability.

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(d) When a trace amount of one or two from among Ni and Co is further combined in the above alloy containing a trace amount of one or more elements of the platinum group and a trace amount

of Nb, Zr, Hf, Ta, and/or Bi, the effect of reducing hydrogen overvoltage of Ni and/or Co is added to the effect of reducing the hydrogen overvoltage of elements of the platinum group and the effects of stabilizing and strengthening passive-state films of Nb, Zr, Hf, Ta, and Bi on titanium, thereby maintaining extremely good resistance to crevice corrosion even when the content of extremely expensive elements of the platinum group is reduced. Further, the deterioration of processability caused by the addition of Ni and/or Co is not pronounced.

(e) When a trace quantity of an element of the platinum group, a trace quantity of Nb, Zr, Hf, Ta, and/or Bi is added, trace quantities of Ni and/or Co are added, and Mo, W, and/or V are added in combination as set forth above, there is no negative effect whatsoever on the cumulative effect of reducing the hydrogen overvoltage of elements of the platinum family and Ni and/or Co; the effects of stabilizing and strengthening passive-state films of Nb, Zr, Hf, Ta, and Bi on titanium; or the effect of stabilizing passive-state films formed on the surface of titanium by the flowing of molybdic acid ions, tungstic acid ions, and/or vanadic acid ions into crevices. These effects intermingle and combine, yielding a titanium alloy with a low content of expensive elements of the platinum family. In this titanium alloy, pronounced deterioration of

processability is prevented by the addition of Mo, W, V, Ni, and/or Co while maintaining excellent resistance to crevice corrosion.

The present invention, devised in light of the above discoveries, is a titanium alloy characterized by a chemical composition comprising, by weight,

one or more elements of the platinum group:

total 0.01 to 0.12 percent,

one or more from among Nb, Zr, Hf, Ta, and Bi:

total 0.05 to 2.00 percent,

and further comprising, as required,

one or more from among Ni and Co:

total 0.05 to 2.00 percent, and/or

one or more from among Mo, W, and V:

total 0.05 to 2.00 percent

with the remainder being essentially comprised of Ti, thereby achieving good resistance to crevice corrosion and good processability.

The reasons for numerically limiting the components of the titanium alloy of the present invention to the above-stated proportions will be given below.

A) Elements of the platinum group (Ru, Rh, Pd, Os, Ir, and Pt)

These components all have equal effects on improving the resistance to corrosion (including the resistance to crevice corrosion) of the titanium alloy. The enhancement effect on corrosion resistance appears at a content of one or more elements of the platinum group of 0.01 percent (the percentages used to denote component proportions hereinafter are weight percentages) or more of the total. The effect becomes more pronounced as the quantity increases. However, when the total content of elements of the platinum group exceeds 12 percent in the presence of Nb, Zr, Hf, Ta, or Bi, the above effect tends to reach saturation. Since this sharply increases the cost of the alloy, the total content of one or more elements of the platinum group is set at 0.01 to 0.12 percent.

B) Nb, Zr, Hf, Ta, and Bi

These components act to stabilize passive-state films on titanium, and in particular, have equal effects on improving resistance to crevice corrosion. In the presence of platinum group elements, particularly low-quantity ranges of platinum group elements (ranges of quantities lower than about the 0.2 percent known for Ti-Pd alloys), marked effects on stabilizing and strengthening passive-state films appear. However, at a total quantity of less than 0.05 percent of one or more from among Nb, Zr, Hf, Ta, and Bi, the effect on improving the

resistance to crevice corrosion as set forth above is inadequate. When incorporated in a total content exceeding 2.00 percent, not only is no further marked effect on improving resistance to crevice corrosion achieved, but the cost of the alloy increases sharply. Thus, the total content of one or more from among Nb, Zr, Hf, Ta, and Bi is set at 0.05 to 2.00 percent.

C) Ni and Co

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Each of these components has an equal effect on reducing the hydrogen overvoltage of the alloy in the same manner as the platinum group elements. Accordingly, they have the effect of improving the corrosion resistance of the titanium alloy. However, this effect becomes more pronounced in the presence of trace quantities of one or more platinum group elements and one or more from among Nb, Zr, Hf, Ta, and Bi. The above effect of improving resistance to corrosion appears when a total content of Ni and Co of 0.05 or more is incorporated. However, when 2.00 percent is exceeded, even in the presence of a platinum group element, processability deteriorates markedly. Thus, the total content of one or more from among Ni and Co is set at 0.05 to 2.00 percent. When considering cold finished products, this content is desirably adjusted to about 0.6 percent or less.

D) Mo, W, and V

In the use environment, Mo, W, and V become ions having an oxidizing effect and flow out into crevices, thereby having a stabilizing effect on the passive-state film on the titanium surface. However, in the presence of prescribed amounts of one or more platinum group elements and one or more from among Nb, Zr, Hf, Ta, and Bi, this effect intermingles and combines with the hydrogen overvoltage reducing effect of the platinum reducing element and the stabilizing and strengthening effects on the passive-state film on titanium of Nb, Zr, Hr, Ta, and Bi so that a good effect on resisting crevice corrosion is produced on the alloy even when the total quantities of platinum group elements and Nb, Zr, Hf, Ta, and Bi are reduced. To stabilize and ensure such effects, it is necessary to add a total quantity of 0.05 percent or more of one or more from among Mo, W, and V. When the total quantity of Mo, W, and V exceeds 2.00 percent, the negative effect on processability of the alloy becomes pronounced.

Accordingly, the total content of one or more from among Mo, W, and V is set at 0.05 to 2.00 percent.

As set forth above, by adding a trace quantity of one or more platinum group elements and one or more from among Nb, Zr, Hf, Ta, and Bi, or, alternatively, by further adding one or more from among Mo, W, and V and/or one or more from among Ni and Co

to titanium, a titanium alloy is obtained that is relatively inexpensive and has good overall corrosion resistance, particularly resistance to crevice corrosion and acidity, without compromising processability. From the perspectives of corrosion resistance and processability, it is desirable for there to be few impurities such as Fa, O, C, N, and H; in particular, care must be exercised with regard to the Fe and O contents. However, since corrosion resistance is particularly strong in the titanium alloy of the present invention, the degree of tolerance for these impurities is greater than in pure titanium; no particular problems are encountered when each of these impurities is kept to less than or equal to about 0.4 percent. Even when less than one percent of Sn and less than 0.2 percent of Cr are contained, there is no marked negative effect with regard to corrosion resistance.

The present invention is described below through embodiments which are contrasted with comparative examples.

<Embodiments>

Commercial industrial-use pure titanium plate (JIS Type 2: comparative alloy 120), Ti-0.2 percent Pd alloy plate (ASTM Grade 7: comparative alloy 119), and Ti-0.8 percent Ni-0.3 percent Mo alloy plate (ASTM Grade 12: comparative alloy 118) were procured and the titanium alloy materials with the

compositions shown in Table 1 were prepared. The titanium alloy materials were prepared by blending sponge titanium and alloy components in the form of pure metal powders, button melting the mixture with an argon-arc furnace device to obtain small ingots, and subjecting the ingots to hot forging, hot rolling, scale removal treatment (sand blasting + acid washing), and cold rolling to a thickness of 4 mm. The alloys were then heat treated (maintained at 700°C for 30 minutes under vacuum and then cooled).

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Table 1, Part 1

Material Number		Chemical Components (Weight Percentages)																	Crevice corrosion resistance	
		Platinum group elements						Nb	Zr	Hf	Ta	Bi	Mo	W	V	Ni	Co	Ti and impurities	Result for 125℃	Result for 200℃
		Ru	Rh	Pd	Os	Ir	Pt													
Alloys of the present invention	1	0.013	-	-	-	-	-	1.72	-	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	2	0.047	-	-	-	-	-	1.25	-	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	3	0.093	-	-	-	-	-	0.89	-	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	4	0.115	-	-	-	-	-	0.11	-	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	5	0.015	-	-	-	-	-	-	1.85	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	6	0.099	-	-	-	-	-	-	1.52	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	7	0.078	-	-	-	-	-	-	0.62	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	8	0.117	-	-	-	-	-	-	0.10	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	9	0.014	-	-	-	-	-	-	-	1.53	-	-	-	-	-	-	-	Remainder	OOO	OOO
	10	0.018	-	-	-	-	-	-	-	-	1.07	-	-	-	-	-	-	Remainder	OOO	OOO
	11	0.011	-	-	-	-	-	-	-	-	-	1.34	-	-	-	-	-	Remainder	OOO	OOO
	12	0.017	-	-	-	-	-	0.52	0.76	0.46	-	-	-	-	-	-	-	Remainder	OOO	OOO
	13	0.016	-	-	-	-	-	-	1.26		0.66	-	-	-	-	-	-	Remainder	OOO	OOO
	14	0.014	-	-	-	-	-	-	-	0.73	0.52	0.62	-	-	-	-	-	Remainder	OOO	OOO
	15	-	-	0.015	-	-	-	1.89	-	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	16	-	-	0.041	-	-	-	1.32	-	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	17	-	-	0.082	-	-	-	0.76	-	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	18	-	-	0.113	-	-	-	0.17	-	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	19	-	-	0.012	-	-	-	-	1.73	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	20	-	-	0.044	-	-	-	-	1.16	-	-	-	-	-	-	-	-	Remainder	OOO	OOO

Table 1, Part 2

Material Number		Chemical Components (Weight Percentages)																	Crevice corrosion resistance	
		Platinum group elements						Nb	Zr	Hf	Ta	Bi	Mo	W	V	Ni	Co	Ti and impurities	Result for 125°C	Result for 200°C
		Ru	Rh	Pd	Os	Ir	Pt													
Alloys of the present invention	21	-	-	0.094	-	-	-	-	0.81	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	22	-	-	0.116	-	-	-	-	0.12	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	23	-	-	0.053	-	-	-	0.25	0.29	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	24	-	-	0.082	-	-	-	0.23	0.31	-	-	0.12	-	-	-	-	-	Remainder	OOO	OOO
	25	-	-	0.113	-	-	-	0.22	-	-	0.09	-	-	-	-	-	-	Remainder	OOO	OOO
	26	-	-	0.035	-	-	-	0.52	0.31	-	0.18	-	-	-	-	-	-	Remainder	OOO	OOO
	27	-	-	0.062	-	-	-	0.23	0.47	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	28	-	-	0.082	-	-	-	0.22	0.22	0.25	-	-	-	-	-	-	-	Remainder	OOO	OOO
	29	-	-	0.053	-	-	-	-	-	0.35	0.22	0.19	-	-	-	-	-	Remainder	OOO	OOO
	30	-	0.012	-	-	-	-	0.22	0.33	0.26	0.50	0.17	-	-	-	-	-	Remainder	OOO	OOO
	31	-	0.032	-	-	-	-	0.32		0.63	-	-	-	-	-	-	-	Remainder	OOO	OOO
	32	-	0.060	-	-	-	-	0.21	0.26	-	1.23	-	-	-	-	-	-	Remainder	OOO	OOO
	33	-	0.091	-	-	-	-	0.33	0.12	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	34	-	0.115	-	-	-	-	-	-	0.35	0.06	0.12	-	-	-	-	-	Remainder	OOO	OOO
	35	-	-	-	0.015	-	-	0.25	0.18	-	1.32	-	-	-	-	-	-	Remainder	OOO	OOO
	36	-	-	-	0.047	-	-	-	0.35	0.72	-	0.57	-	-	-	-	-	Remainder	OOO	OOO
	37	-	-	-	0.089	-	-	0.31	0.25	-	0.72	-	-	-	-	-	-	Remainder	OOO	OOO
	38	-	-	-	0.110	-	-	0.23	-	0.12	-	0.13	-	-	-	-	-	Remainder	OOO	OOO
	39	-	-	-	0.060	-	-	-	0.35	0.90	0.21	-	-	-	-	-	-	Remainder	OOO	OOO
	40	-	-	-	-	0.012	-	-	0.33	-	-	-	-	-	-	-	-	Remainder	OOO	OOO

Table 1, Part 3

Material Number		Chemical Components (Weight Percentages)																	Crevice corrosion resistance	
		Platinum group elements						Nb	Zr	Hf	Ta	Bi	Mo	W	V	Ni	Co	Ti and impurities	Result for 125°C	Result for 200°C
		Ru	Rh	Pd	Os	Ir	Pt													
Alloys of the present invention	41	-	-	-	-	0.053	-	0.26	0.23	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	42	-	-	-	-	0.089	-	-	0.22	0.31	0.11	0.12	-	-	-	-	-	Remainder	OOO	OOO
	43	-	-	-	-	0.113	-	-	0.25	-	0.31	-	-	-	-	-	-	Remainder	OOO	OOO
	44	-	-	-	-	0.043	-	-	0.26	0.21	-	-	-	-	-	-	-	Remainder	OOO	OOO
	45	-	-	-	-	-	0.016	0.32	0.72	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	46	-	-	-	-	-	0.051	0.26	0.22	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	47	-	-	-	-	-	0.092	-	0.22	0.31	0.25	-	-	-	-	-	-	Remainder	OOO	OOO
	48	-	-	-	-	-	0.111	-	0.11	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	49	-	-	-	-	-	0.112	0.13	-	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	50	0.007	-	0.011	-	-	-	0.35	0.21	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	51	0.021	-	0.026	-	-	-	1.25	-	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	52	0.023	-	0.024	-	-	-	-	0.85	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	53	0.042	-	0.011	-	-	-	-	-	1.69	-	-	-	-	-	-	-	Remainder	OOO	OOO
	54	0.012	-	0.014	-	-	-	-	-	-	0.27	-	-	-	-	-	-	Remainder	OOO	OOO
	55	0.012	-	0.013	-	-	-	-	-	-	-	1.93	-	-	-	-	-	Remainder	OOO	OOO
	56	0.015	-	0.013	-	-	-	1.02	0.97	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	57	0.025	-	0.016	-	-	-	0.87	-	0.99	-	-	-	-	-	-	-	Remainder	OOO	OOO
	58	0.013	-	0.025	-	-	-	0.89	-	-	1.09	-	-	-	-	-	-	Remainder	OOO	OOO
	59	0.011	-	0.022	-	-	-	0.94	-	-	-	0.97	-	-	-	-	-	Remainder	OOO	OOO
	60	0.013	0.014	-	-	-	-	12	-	0.16	-	-	-	-	-	-	-	Remainder	OOO	OOO

Table 1, Part 4

Material Number		Chemical Components (Weight Percentages)																	Crevice corrosion resistance	
		Platinum group elements						Nb	Zr	Hf	Ta	Bi	Mo	W	V	Ni	Co	Ti and impurities	Result for 125°C	Result for 200°C
		Ru	Rh	Pd	Os	Ir	Pt													
Alloys of the present invention	61	0.015	0.012	-	-	-	-	0.52	0.76	0.46	-	-	-	-	-	-	-	Remainder	ООО	ООО
	62	0.012	0.014	-	-	-	-	1.23	0.36	-	0.24	-	-	-	-	-	-	Remainder	ООО	ООО
	63	0.016	0.012	-	-	-	-	0.75	-	0.19	1.03	-	-	-	-	-	-	Remainder	ООО	ООО
	64	-	0.014	0.012	-	-	-	0.22	-	0.23	-	1.49	-	-	-	-	-	Remainder	ООО	ООО
	65	-	0.015	0.026	-	-	-	-	0.76	0.31	0.52	-	-	-	-	-	-	Remainder	ООО	ООО
	66	-	0.009	0.025	-	-	-	-	0.97	-	0.23	0.16	-	-	-	-	-	Remainder	ООО	ООО
	67	-	0.016	0.014	-	-	-	-	0.25	1.32	-	-	-	-	-	-	-	Remainder	ООО	ООО
	68	0.013	-	-	-	-	0.012	-	1.15	0.77	-	-	-	-	-	-	-	Remainder	ООО	ООО
	69	-	-	0.015	-	-	0.021	-	1.26	-	0.53	-	-	-	-	-	-	Remainder	ООО	ООО
	70	-	-	0.012	0.012	0.007	-	-	0.87	-	-	0.95	-	-	-	-	-	Remainder	ООО	ООО
	71	-	0.012	-	0.006	0.013	-	-	-	0.87	-	0.55	-	-	-	-	-	Remainder	ООО	ООО
	72	-	-	0.013	-	0.021	0.015	-	-	1.25	0.63	-	-	-	-	-	-	Remainder	ООО	ООО
	73	-	-	-	-	-	-	-	-	-	1.32	0.52	-	-	-	-	-	Remainder	ООО	ООО
	74	0.039	-	-	-	-	-	0.15	-	-	-	-	0.15	-	-	-	-	Remainder	ООО	ООО
	75	0.041	-	-	-	-	-	-	0.75	-	-	-	0.22	-	-	-	-	Remainder	ООО	ООО
	76	0.033	-	-	-	-	-	-	0.25	-	-	-	0.15	0.15	-	-	-	Remainder	ООО	ООО
	77	0.038	-	-	-	-	-	-	0.22	-	-	-	0.17	-	0.30	-	-	Remainder	ООО	ООО
	78	0.045	-	-	-	-	-	-	0.11	-	-	-	0.15	-	-	0.15	-	Remainder	ООО	ООО
	79	0.039	-	-	-	-	-	-	0.25	-	-	-	0.12	-	-	-	0.13	Remainder	ООО	ООО
	80	0.045	-	-	-	-	-	0.10	0.12	-	-	-	0.11	-	-	-	0.15	Remainder	ООО	ООО

Table 1, Part 5

Material Number		Chemical Components (Weight Percentages)																	Crevice corrosion resistance	
		Platinum group elements						Nb	Zr	Hf	Ta	Bi	Mo	W	V	Ni	Co	Ti and impurities	Result for 125°C	Result for 200°C
		Ru	Rh	Pd	Os	Ir	Pt													
Alloys of the present invention	81	0.011	-	0.016	-	-	-	0.12	-	-	-	-	0.15	-	-	0.32	-	Remainder	000	000
	82	0.014	-	-	-	-	-	-	0.09	-	-	-	0.21	-	-	0.25	-	Remainder	000	000
	83	0.035	-	-	-	-	-	-	0.15	-	-	-	0.26	-	-	-	0.23	Remainder	000	000
	84	-	-	0.033	-	-	-	-	0.20	-	-	-	0.24	-	-	-	-	Remainder	000	000
	85	-	-	0.035	-	-	-	-	0.26	-	-	-	-	-	-	0.31	0.15	Remainder	000	000
	86	0.008	0.011	0.012	-	-	-	-	0.26	-	-	-	0.25	-	-	-	-	Remainder	000	000
	87	-	-	0.013	-	-	0.012	0.12	0.11	-	-	-	0.25	-	-	0.52	-	Remainder	000	000
	88	0.012	-	-	-	-	-	-	0.22	-	-	-	-	-	-	0.32	-	Remainder	000	000
	89	0.012	-	-	-	-	-	-	0.15	-	-	-	-	-	-	-	0.29	Remainder	000	000
	90	0.013	-	-	-	-	-	-	0.25	-	-	-	0.22	0.12	0.21	-	-	Remainder	000	000
	91	0.031	-	-	-	-	-	0.11	0.15	-	-	0.12	0.15	-	0.13	-	0.17	Remainder	000	000
	92	0.052	-	-	-	-	-	0.12	-	-	-	-	-	-	-	-	0.43	Remainder	000	000
	93	0.042	-	-	-	-	-	-	0.21	0.13	0.17	-	-	0.02	-	0.09	-	Remainder	000	000
	94	0.038	-	-	-	-	-	-	0.16	-	0.12	0.17	0.23	-	-	-	0.21	Remainder	000	000
	95	0.032	-	-	-	-	-	-	0.17	0.16	0.14	-	-	-	0.18	0.23	0.09	Remainder	000	000
	96	0.013	-	0.021	-	-	-	-	0.25	-	-	-	0.31	-	-	-	0.29	Remainder	000	000
	97	0.012	-	0.031	-	-	-	-	-	-	0.30	-	0.21	-	-	-	-	Remainder	000	000
	98	0.016	-	0.015	-	-	-	-	-	-	0.50	-	-	0.59	-	0.25	0.31	Remainder	000	000
	99	-	0.021	0.013	-	0.012	-	-	-	0.29	-	-	0.31	-	-	0.52	-	Remainder	000	000
	100	-	-	-	0.013	0.014	-	0.17	0.15	-	-	-	0.19	-	0.21	-	0.18	Remainder	000	000

Table 1, Part 6

Material Number		Chemical Components (Weight Percentages)																	Crevice corrosion resistance	
		Platinum group elements						Nb	Zr	Hf	Ta	Bi	Mo	W	V	Ni	Co	Ti and impurities	Result for 125°C	Result for 200°C
		Ru	Rh	Pd	Os	Ir	Pt													
Alloys of the present invention	101	0.052	-	-	-	-	-	-	0.13	-	-	-	-	-	-	0.45	-	Remainder	OOO	OOO
	102	0.049	-	-	-	-	-	-	0.17	-	-	-	-	-	-	-	0.52	Remainder	OOO	OOO
	103	-	-	0.053	-	-	-	-	0.11	-	-	-	-	-	-	0.55	-	Remainder	OOO	OOO
	104	-	-	0.049	-	-	-	-	0.09	-	-	-	-	-	-	-	0.45	Remainder	OOO	OOO
Comparative alloys	105	-	-	-	-	-	-	1.97	-	-	-	-	-	-	-	-	-	Remainder	XXX	XXX
	106	-	-	-	-	-	-	-	2.03	-	-	-	-	-	-	-	-	Remainder	XXX	XXX
	107	-	-	0.10	-	-	-	-	-	-	-	-	-	-	-	-	-	Remainder	OOO	XXX
	108	-	-	-	-	-	-	0.03	-	-	0.09	-	-	-	-	-	0.06	Remainder	XXX	XXX
	109	-	-	-	-	-	0.007	-	-	-	-	0.52	-	-	-	-	-	Remainder	XΔΔ	XXX
	110	-	-	0.013	-	-	-	-	0.32	-	-	-	-	-	-	-	-	Remainder	XΔΔ	XXX
	111	-	-	0.011	-	-	-	0.09	-	-	-	-	-	-	-	-	-	Remainder	ΔΔΔ	XXX
	112	0.003	-	0.008	-	-	-	-	-	-	0.12	-	-	-	-	-	-	Remainder	ΔXΔ	XXX
	113	0.007	-	-	-	-	-	-	0.52	-	-	-	-	-	-	-	-	Remainder	XΔX	XXX
	114	0.009	-	-	-	-	-	-	-	0.26	-	-	-	-	-	-	-	Remainder	XΔX	XXX
	115	-	-	-	-	-	-	-	-	-	0.21	-	-	-	-	-	-	Remainder	XΔΔ	XXX
	116	0.005	-	-	-	-	-	0.50	-	-	-	-	-	-	-	-	-	Remainder	OΔΔ	XXX
	117	-	-	-	-	-	-	-	-	-	-	0.06	-	-	-	-	-	Remainder	XXX	XXX
	118	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	0.8	-	Remainder	OOO	XXX
	119	-	-	0.21	-	-	-	-	-	-	-	-	-	-	-	-	-	Remainder	OOO	OOO
	120	Industrial-use pure titanium																	XXX	XXX

Next, test pieces measuring 2 mm in thickness by 30 mm in width by 30 mm in length (with a hole 7 mm in diameter in the center) were collected from each material and abraded with No. 600 Emory paper to obtain samples with crevice corrosion.

Teflon sheets measuring 2 mm in thickness by 40 mm in width by 40 mm in length (with a hole 7 mm in diameter in the center) were sandwiched between two sheets of crevice corrosion sample and secured through Teflon bushings using titanium bolts and nuts to complete the assembly of crevice corrosion test pieces. Next, employing a Teflon-lined autoclave, pairs of the above sample pieces prepared in sets of three for each material were immersed for 500 hours in a 25 percent NaCl aqueous solution (pH 6) at 125°C and 200°C to examine the state of crevice corrosion.

The crevice corrosion test results thus obtained are given in Table 1.

In evaluating the resistance to crevice corrosion, the following three-level scale was employed: 0=no crevice corrosion; Δ=slight crevice corrosion; and X=marked crevice corrosion.

As is clear from the results shown in Table 1, although the alloys of the present invention were inexpensive, they exhibited

resistance to crevice corrosion that was similar to that of expensive high Ti-0.2 percent Pd alloy.

Further, in a separately implemented corrosion test, the alloys of the present invention exhibited good corrosion resistance equivalent to that of Ti-0.2 percent Pd alloy even in various acid environments such as HCl, H_2SO_4, and HNO_3. Further, in a processability test, they exhibited good processability with no particular obstacles to practical use.

<Comprehensive Effect>

As described above, the present invention inexpensively provides titanium alloys affording at once both good resistance to crevice corrosion and processability. This permits improved reliability and performance of equipment and devices employed in corrosive environments and thus constitutes an extremely useful effect from an industrial perspective.